EUV SCATTEROMETRY FOR HIGH ACCURACY CHARACTERIZATION OF MASK ROUGHNESS

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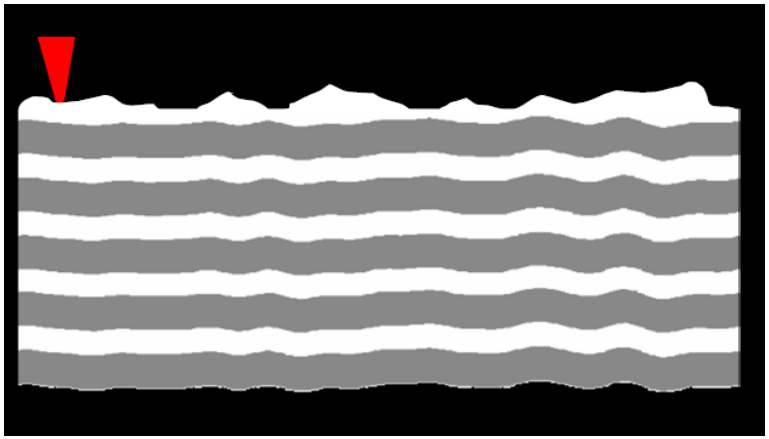
WHY DO WE NEED EUV SCATTEROMETRY?

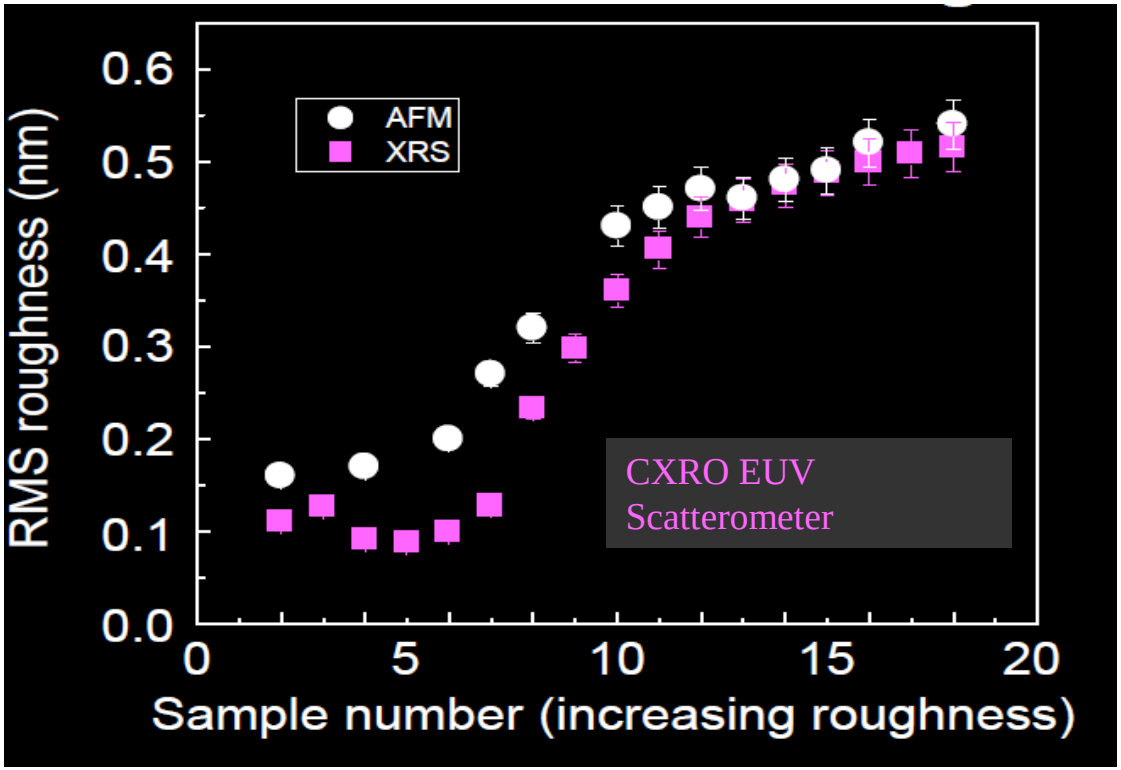
- Scatterometry is a versatile metrology for characterizing periodic structures, regarding critical dimension (CD), and other profile properties
- EUV scatterometry-based measurement
  - Mask phase roughness is one of the contributors to the line edge roughness
  - At 13.5 nm, even small roughness on a mask can introduce significant phase modulation that affects the replication of the mask objects on the wafer
  - It is important to determine a valid metrology to characterize the phase roughness of EUV mask

AFM-BASED ROUGHNESS MEASUREMENT

- AFM-based Roughness
  - Measures only the top surface of the mask
  - Loses information about multilayer structures, such as termed replicated surface roughness (RSR) and interfacial effects
  - The measurement is more qualitative than quantitative



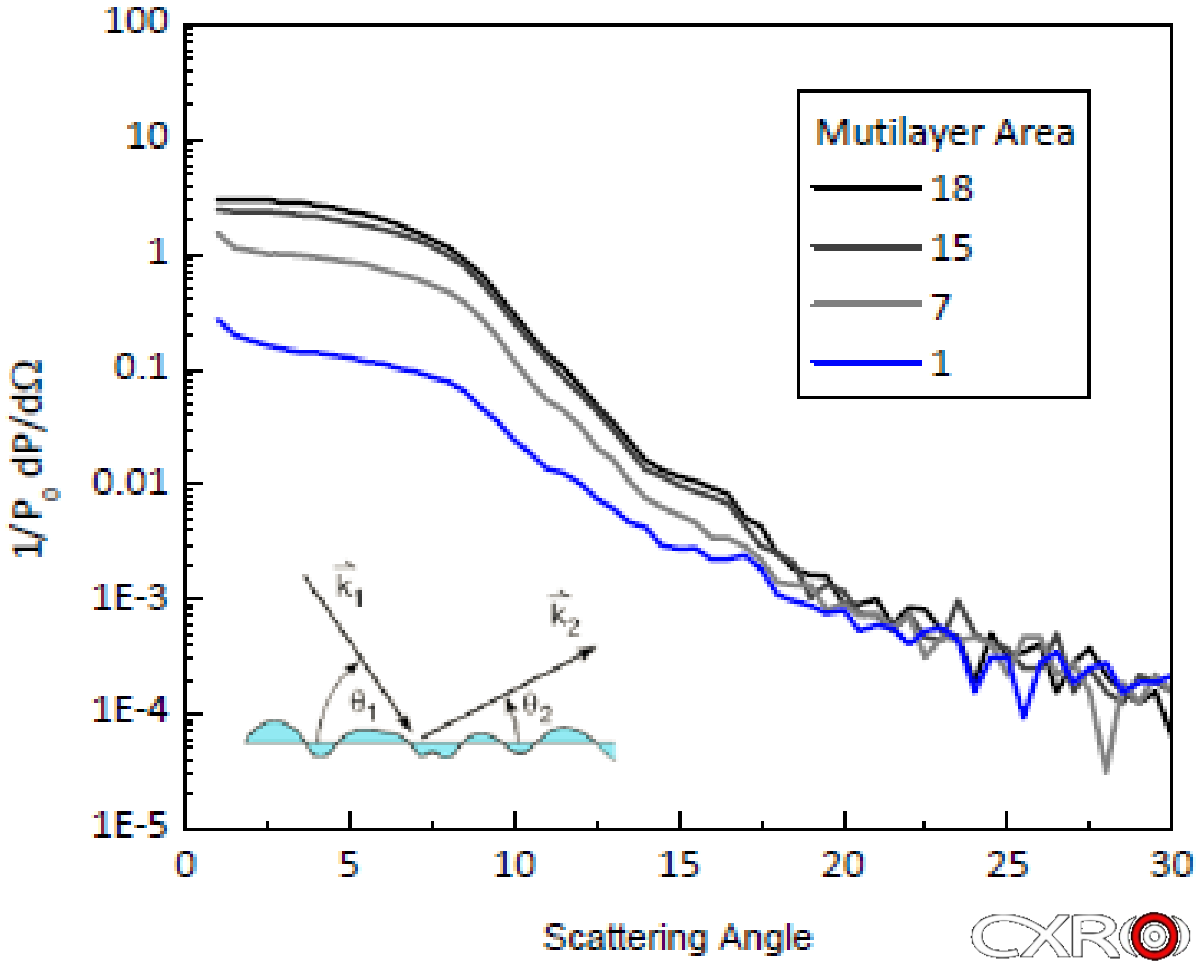
AFM IS BLIND TO TRUE EUV ROUGHNESS



- EUV Scatterometry provides a more accurate approach to the characterization of the effective phase roughness of a multilayer
- There are Discrepancies between AFM and EUV scatterometry measured roughness: AFM overestimates the true EUV roughness of the multilayer

* Simi George, et al, "Experimental verification of EUV mask lithographic patterning and line edge roughness", EUV lithography II, Proc. Of SPIE Vol.79690E, 2011

EUV SCATTEROMETRY AT CXRO



Angle resolved scattering measurements obtained for the rough mask multilayer surface. Increasing in scattering intensities as a function of roughness of the substrate.

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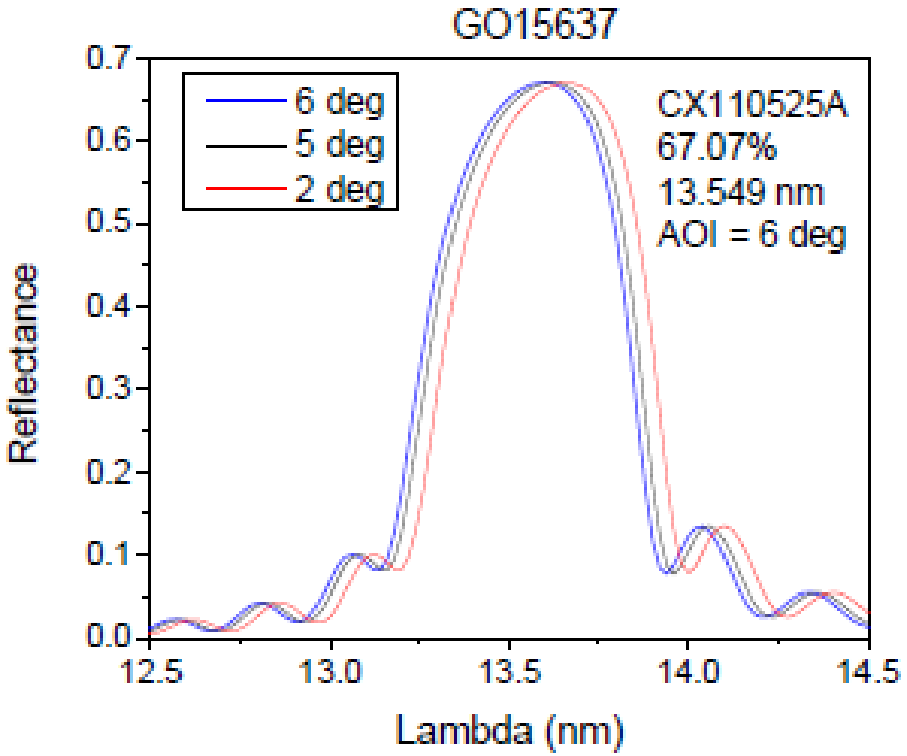
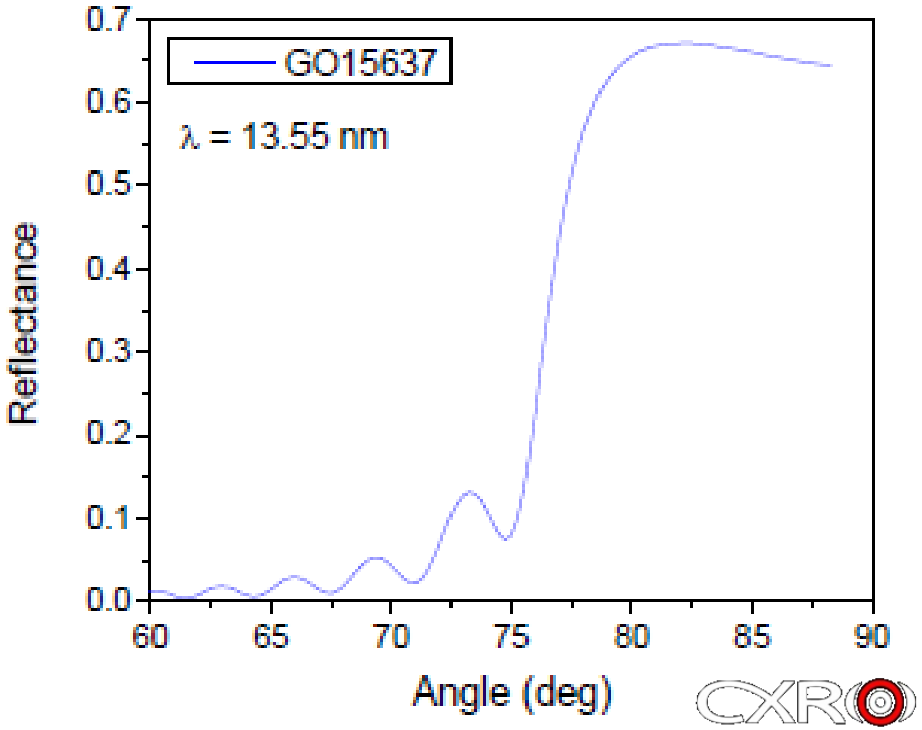
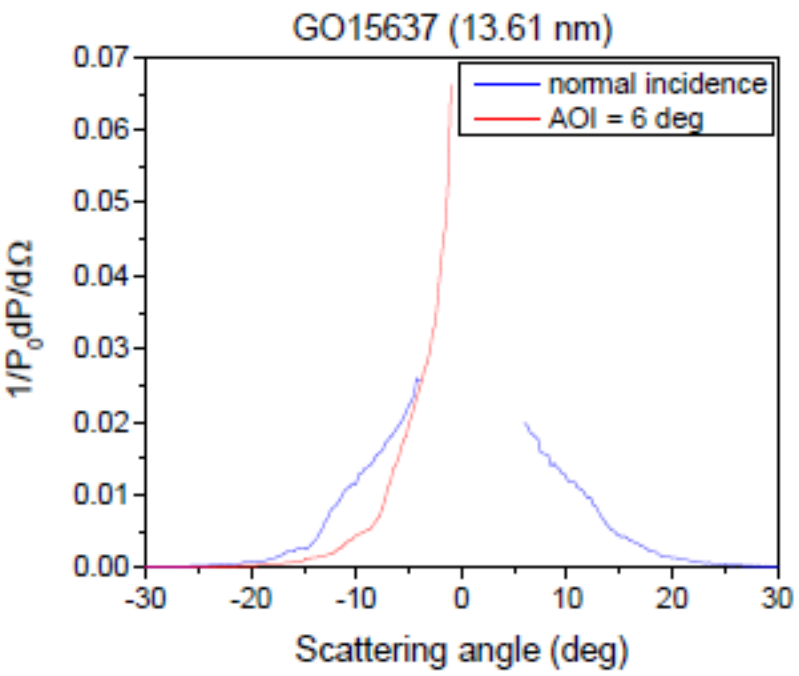
REFLECTIVITY OF MULTILAYER SAMPLE

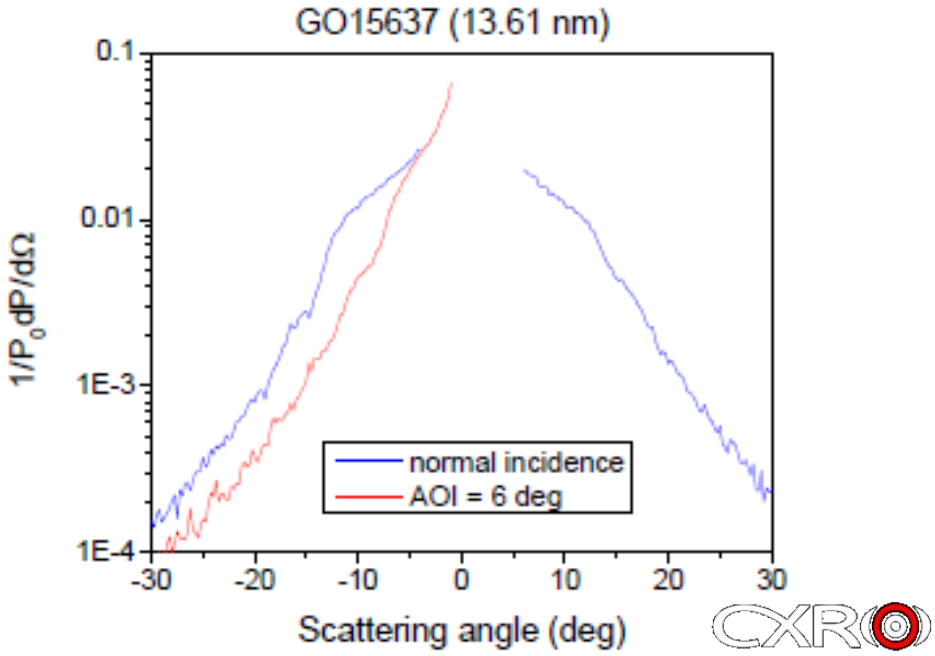




- The reflectivity vs wavelength at angles of incidence of 2,5,6 degrees.
- The reflectivity versus angle at a fixed wavelength of 13.55 nm

EUV SCATTEROMETRY AT CXRO





- The angular scattering distribution for normal incidence and 6 degrees incidence.
- The scattering angle is measured from the specularly reflected beam.
- The asymmetry observed at normal incidence indicates off-normal propagation of the roughness in the multilayer.

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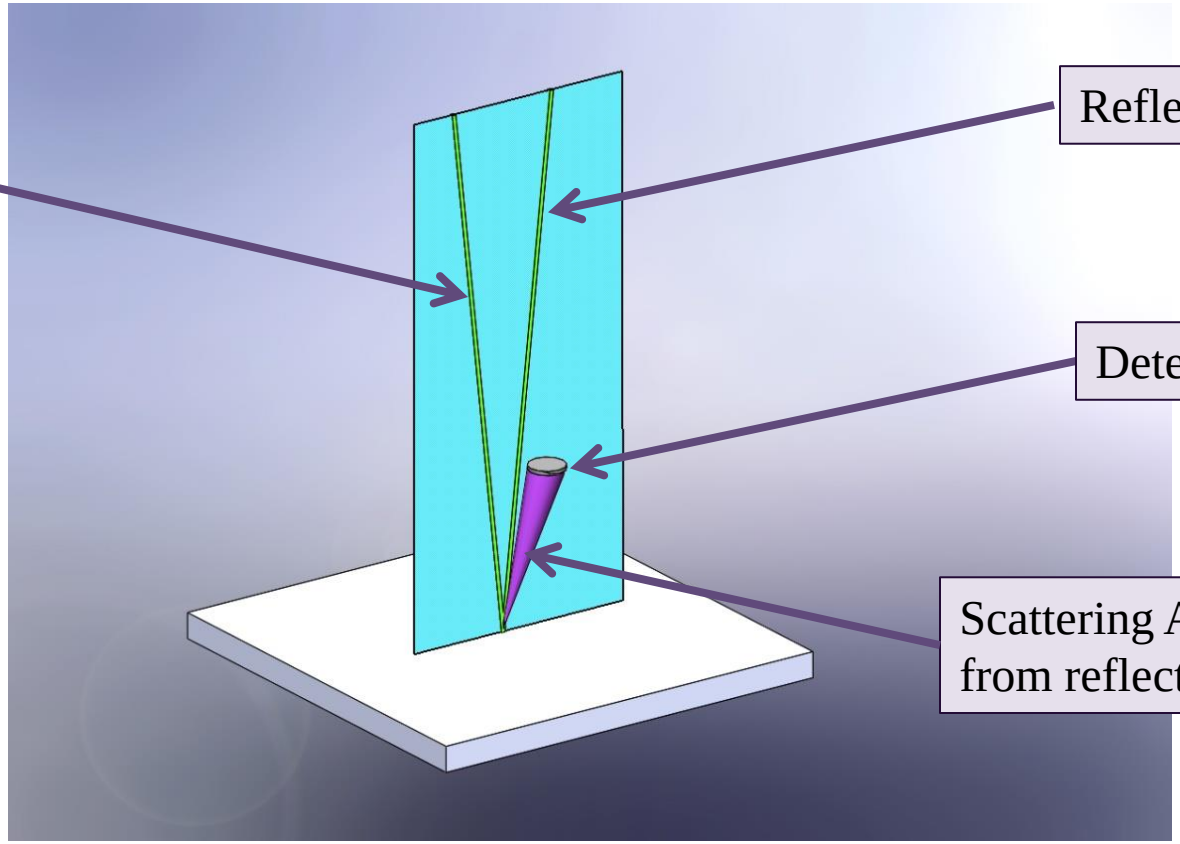
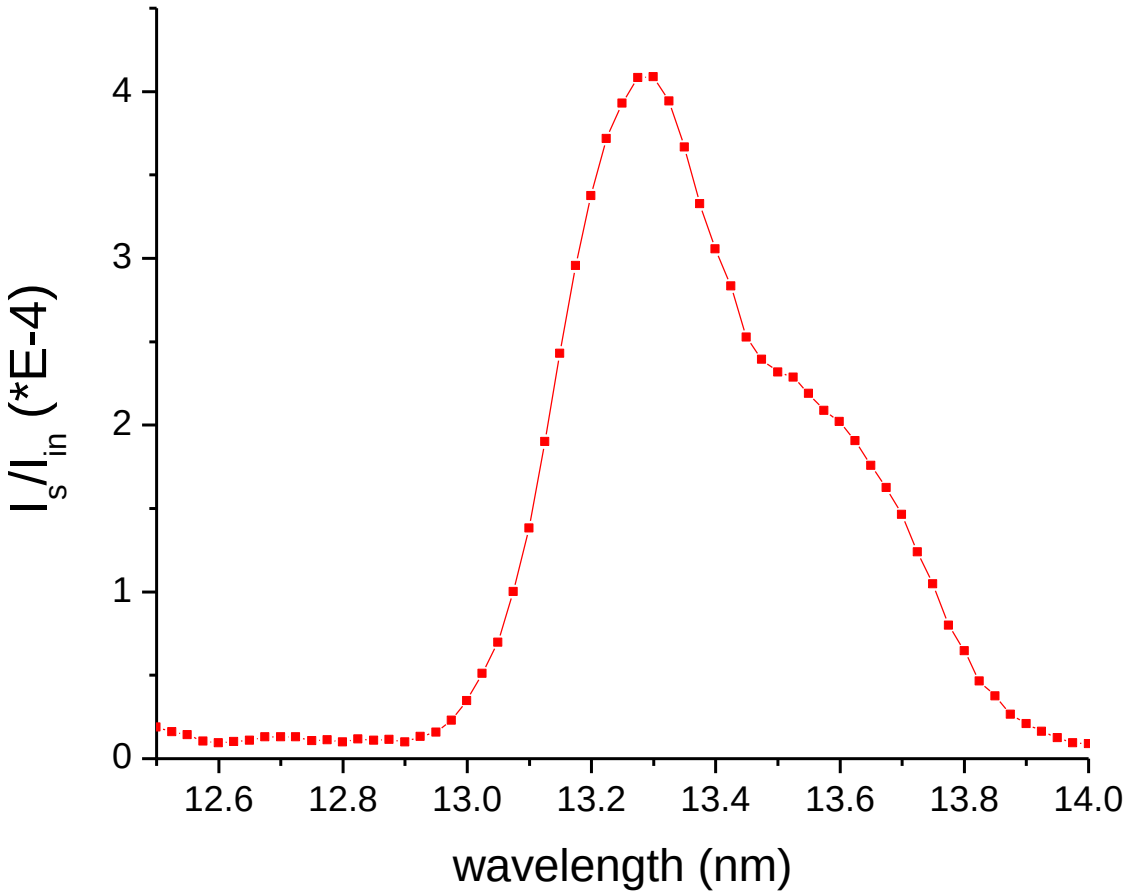
* E. Gullikson and D. Stearns Phys. Rev. B 59, 13273 (1999)

EUV SCATTEROMETRY EXPERIMENT AT EUV TECH



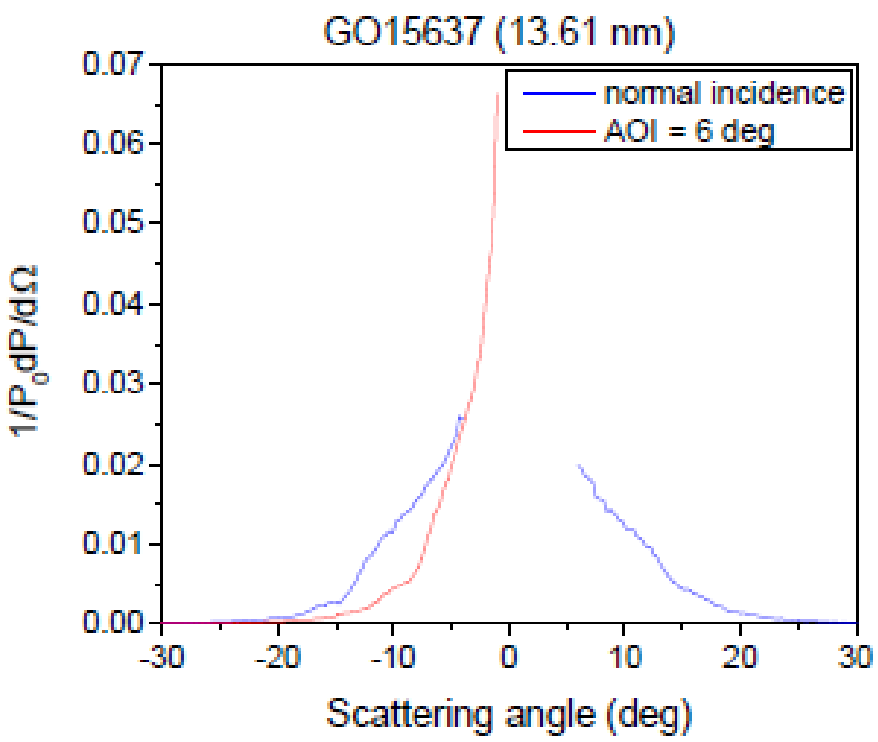
Ratio of scattered Intensity to incident intensity of 2 X 10^{-4} agrees well with ALS measurements

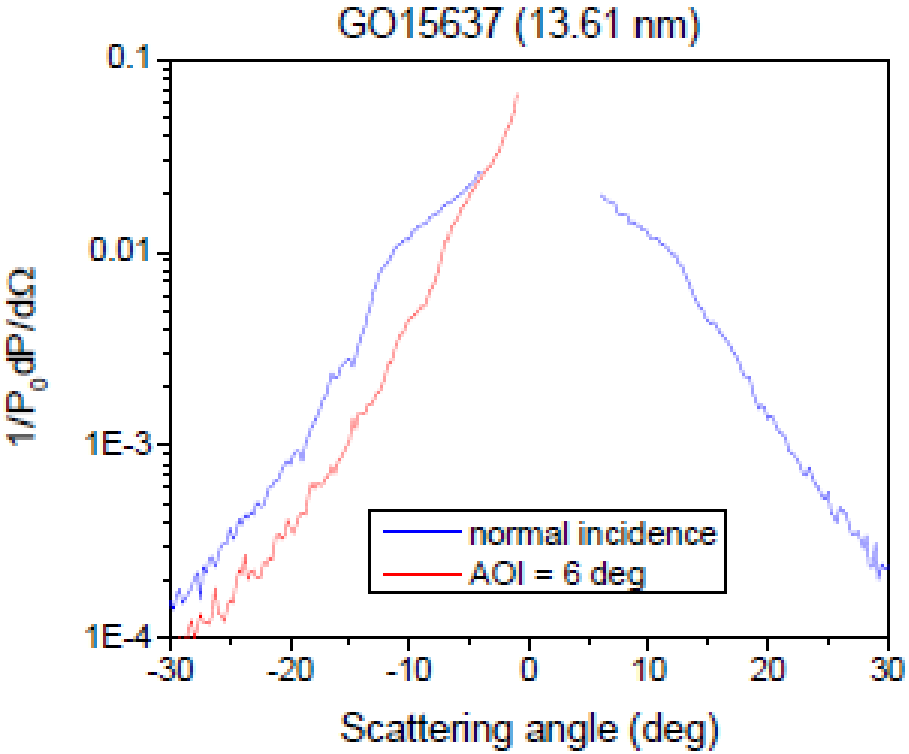
MEASURED SCATTERED INTENSITY VS. WAVELENGTH



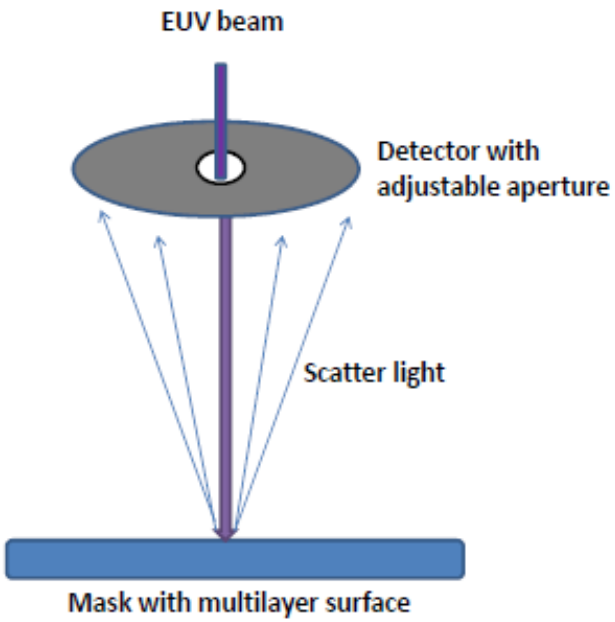
Measured on EUV Tech's Scatterometer using an LPP EUV light Source

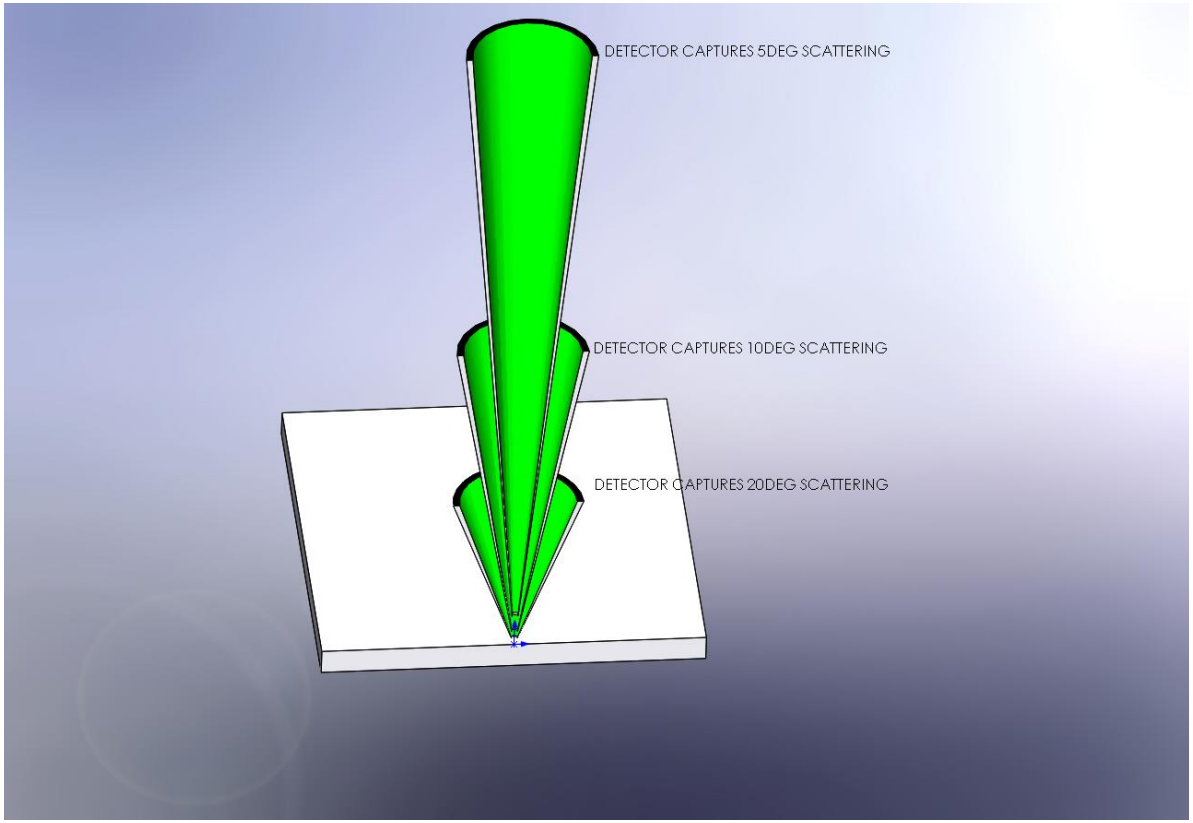
EUV SCATTEROMETRY AT CXRO





ANNULAR DETECTOR FOR EUV SCATTEROMETRY





- Novel detector to achieve angular resolved scatterometry
- For annular detector
  - Angle of 10 degrees and d(theta) = 1.0 degrees
  - Fraction of incident light scattered into annulus detector = 0.03

SUMMARY

- EUV Scatterometry is important to characterize the phase roughness of an EUV mask
- Novel annular detector allows scanning of multiple scattering angles with same detector
- Standalone EUV scatterometry-based measurement correlate very well to ALS measure results

THANK YOU!